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Flying IFR with GPS: How Much Practice Is Needed?

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Summary

Sixteen instrument-rated pilots with no prior experience with IFR GPS completed a program of ground study and five practice flights in an airplane. Eight pilots completed the ground study following a self-study program, while eight pilots received dual ground instruction. The ground study and flight practice covered knowledge and skills required by the instrument rating practical test standard that are affected by the use of IFR GPS. A detailed record was kept of errors made by pilots during each practice flight for six selected skills. The data were analyzed to determine: (1) whether or not the ground study and five practice flights were enough to allow pilots to master the skills; (2) how effective was self study compared to dual instruction; and (3) which skills presented pilots with the most difficulty and accounted for the most errors. The results show that pilots had still not reached proficiency after five practice flights, regardless of ground study method used. Furthermore, pilots were highly similar in the errors they committed while acquiring these new skills. These results show that the learning challenges for proficient use of IFR GPS are significant.

Introduction

Since the late 1990s, the installation of IFR-approved GPS units in general aviation aircraft has steadily increased. Initial studies of GPS usage [Heron et al, 1997; Henry et al, 1999; Adams et al, 2001] have prompted concern about what sorts of additional knowledge or experience might be required to safely use GPS as a primary means of navigation under instrument flight rules.

The FAA has slowly and conservatively taken advisory and regulatory steps toward insuring the safe use of IFR GPS. The Aeronautical Information Manual [FAA, 2004] has been expanded to include a section about IFR GPS. The Instrument Rating Practical Test Standard has also been modified to require every pilot applicant to demonstrate proficiency with IFR GPS when an IFR GPS-equipped aircraft is used for a practical test. These measures are easily side-stepped by pilots who elect to not read the AIM, by pilots who are already instrument-rated, and by pilots who use non-GPS-equipped aircraft for their practical tests.

The idea that additional training or experience might be required for IFR GPS is not only is a question of safety, but also but also one of popular acceptance. Most users of IFR GPS would object to new regulations that require additional and expensive pilot training if the need for such training was not carefully documented and made explicitly clear.

We studied a group of sixteen instrument-rated pilots with no prior experience with IFR GPS as they worked toward proficiency with flying under IFR with GPS. Pilots' learning efforts consisted of two parts: (1) ground study; and (2) five practice flights in which pilots practiced the skills they learned on the ground. Eight pilots completed the ground study through dual instruction, while eight pilots studied the same material on their own.

During the practice flights, a detailed record was made of all errors committed by pilots when practicing six selected skills. The skills are:

1. Program IFR flight plan and load GPS approach
2. Program and fly a VNAV descent
3. Demonstrate a straight-in GPS approach
4. Demonstrate a vectored GPS approach

5. Demonstrate a missed approach and hold
6. Demonstrate a GPS approach w/ procedure turn

The ground study and the flight practice covered other knowledge and skills required for safe and proficient use of IFR GPS, but they were not measured as part of the experiment.

Pilots' error data were analyzed to address three questions:

1. Was ground study and five flight practice enough for the average instrument pilot to master the six skills?
2. How effective was self study compared to dual instruction?
3. Which skills presented pilots with the most difficulty and accounted for the most errors that pilots made?

Method

Participants

Sixteen instrument-rated pilots were recruited from local professional flight training schools. Pilots ranged from 120 to 3,700 hours of flight experience, with a median of 522 hours. Pilots were told they would not be paid for their participation but would receive instrument flight experience using IFR GPS.

Procedure

Eight pilots were assigned to the Self Study group and were told that they would be required to learn the new skills on their own. These pilots were assigned readings in a textbook [Casner, 2002] prior to each session. Pilots were told to master the material as best as they could, and that during the next session, they would have the opportunity to practice and demonstrate their newly learned skills in flight. It was emphasized that pilots' should attempt to master the skills such that they could demonstrate them without the need for intervention by the experimenter, although intervention would be available if needed.

The eight remaining pilots were assigned to the Dual Instruction group and were told to do nothing to prepare for the flight sessions. These pilots were told that the experimenter would cover all of the concepts and skills needed for each flight during a dual ground instruction session immediately prior to the flight. Pilots were told that they should attempt to master the skills such that they could demonstrate them without the need for intervention by the experimenter, although intervention would be available if needed.

Both groups of pilots had unlimited access to a desktop IFR GPS unit that could be used to learn and practice GPS skills prior to each practice flight. The desktop IFR GPS unit was the same make and model installed in the airplane that was used for the practice flights.

For both groups, prior to each practice flight, the experimenter briefly reviewed the skills that would be needed during the flight, provided the pilot with charts covering the routes and approaches to be flown, and answered any questions the pilot had about the material.

The six skills were introduced before the practice flights as shown in Figure 1. Figure 1 also lists the number of times that each skill was practiced during each flight. Note that no new skills were introduced during the fifth practice flight.

Skill	Flt 1	Flt 2	Flt 3	Flt 4	Flt 5
Program IFR flight plan and load GPS approach	1	3	3	3	4
Program and fly a VNAV descent	1				1
Demonstrate a straight-in GPS approach	1			1	
Demonstrate a vectored GPS approach		3	3	1	3
Demonstrate a missed approach and hold			1		1
Demonstrate a GPS approach w/ procedure turn				1	1

Figure 1: Six IFR GPS skills practiced during the five practice flights.

During the practice flights, the experimenter rode in the right seat and did not operate the controls. A script for each flight was prepared in advance and used by the experimenter to ensure that each flight proceeded in accordance to a set plan, and that each pilot was asked to practice and perform the same skills in the same order. The scripts used for each flight are given in Appendix A.

A handheld computer was used to record any interventions required by the experimenter for any skill, errors made by the pilot on any skill, or assistance requested by the pilot for any skill. Interventions were recorded for each pilot and flight. For each skill, if the pilot was able to demonstrate the skill with no intervention on the part of the experimenter, the pilot received a score of 1. If an intervention of any form, regardless of how subtle (e.g., words, gestures, sounds), was required, a score of 0 was recorded for that skill.

Results and Discussion

Figures 2(a) and 2(b) show the error rates for each of the skills during each of the five flights, for both the Self Study and the Dual Instruction groups.

1. Were five practice flights enough?

The first question to address is whether or not ground study and five practice flights were enough to allow pilots to reach proficiency with the six skills. Looking at the data points for the fifth practice flight in both graphs in Figure 2 we can see that the results are mostly unimpressive. Applying the criteria specified in the Instrument Rating - Airplane practical test standard [FAA, 1998], the data suggest that few, if any, of the pilots would meet the standards. Pilots failed to consistently perform all of the GPS approach procedures. In fact, programming a route was the only skill that consistently met PTS standards after five flights.

It is interesting to look at the relationship between the total flight experience of the participants in the study, and their performance on the six skills. The correlation coefficient for total flight hours and overall performance on the six IFR GPS skills for all sixteen pilots was R=0.01. It appears that proficiency with cockpit automation is a separate set of skills to be acquired. Having extensive flight experience in airplanes not equipped with IFR GPS does not appear to help. Flying proficiently with IFR GPS seems to be the result of training and experience flying with IFR GPS.

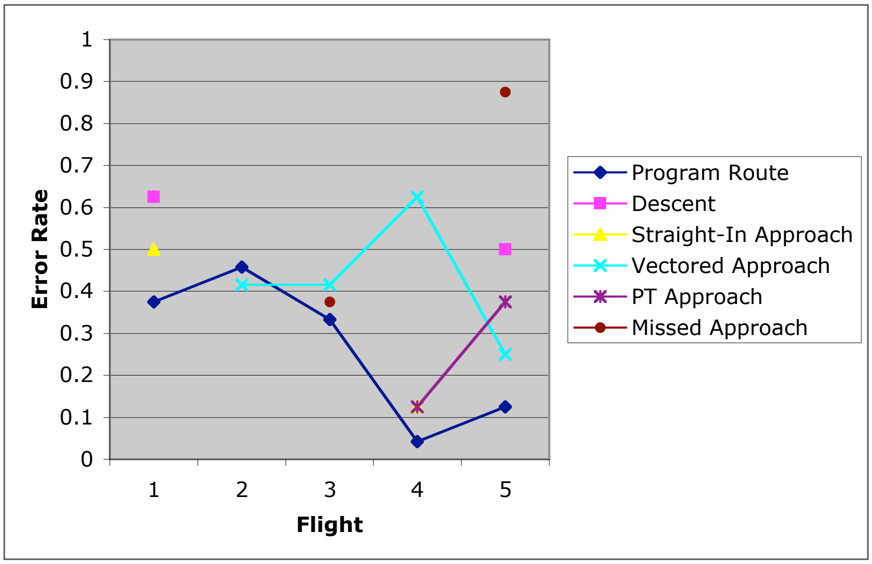

Figure 2(a): Error rates for the six skills (dual instruction)

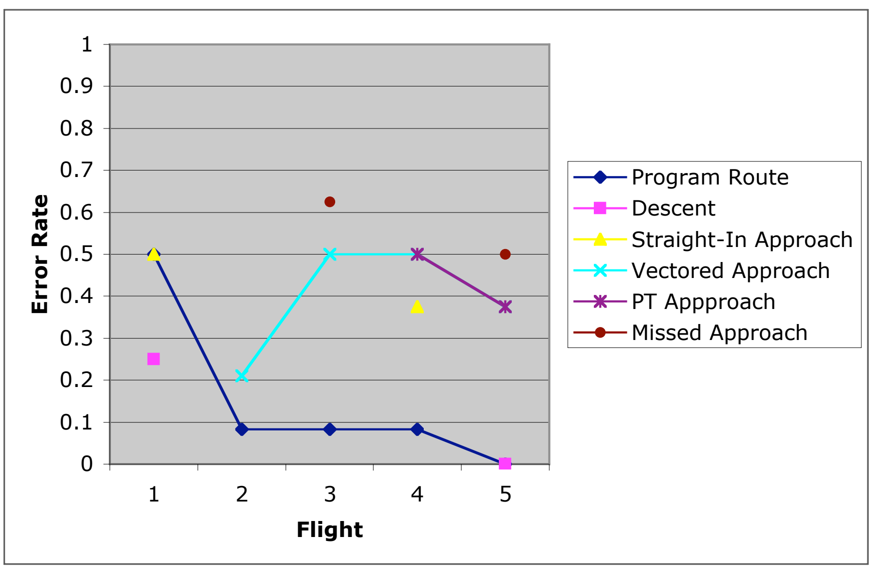

Figure 2(b): Error rates for the six skills (self study)

2. Was there a difference between dual instruction and self study?

A second question to consider is whether or not there are any observed differences between the two methods of ground study: dual instruction and self study. Dual instruction seems to offer the advantage of two-way interaction between student and instructor. Self study offers the advantage of a persistent record of the instructional material that can be later reviewed. It is interesting to note that none of the pilots in the Dual Instruction group made use of notes.

Comparing performance on the individual skills across the dual instruction and self study groups, only the Build and Fly Descent task yielded a significant difference ($t = 2.65$, $p < 0.05$). Since this task was only practiced twice during the course of the five practice flights, no strong conclusions are warranted. It seems that the two ground learning methods yielded similar results.

3. What were the reasons for unsatisfactory performance?

Figures 3 through 8 show the specific criteria that were used by the experimenter to evaluate pilot performance for each of the six tested skills. The data in Figures 3 through 8 break down overall performance for each skill into performance on component sub-skills. Figures 3 through 8 show the sub-skills associated with each skill, and show the proportion of cases for which each sub-skill was a contributing factor in pilots' failure to perform each of the six skills.

Since no significant differences were found between the two learning methods, Figures 3 through 8 combine the results for the two ground learning methods.

Program Route and Install GPS Approach

The Route Programming skill consisted of two sub-skills shown in Figure 3.

The Programming sub-skill required pilots to recall and perform the knobs-and-dials procedures needed to install the route. This sub-skill is essentially a memory task aided by any cues provided by the GPS unit interface. For example, a button marked FPLN might allow pilots to successfully reach the flight planning page when the procedure has not been memorized. The Programming sub-skill was the principle cause for the occasional

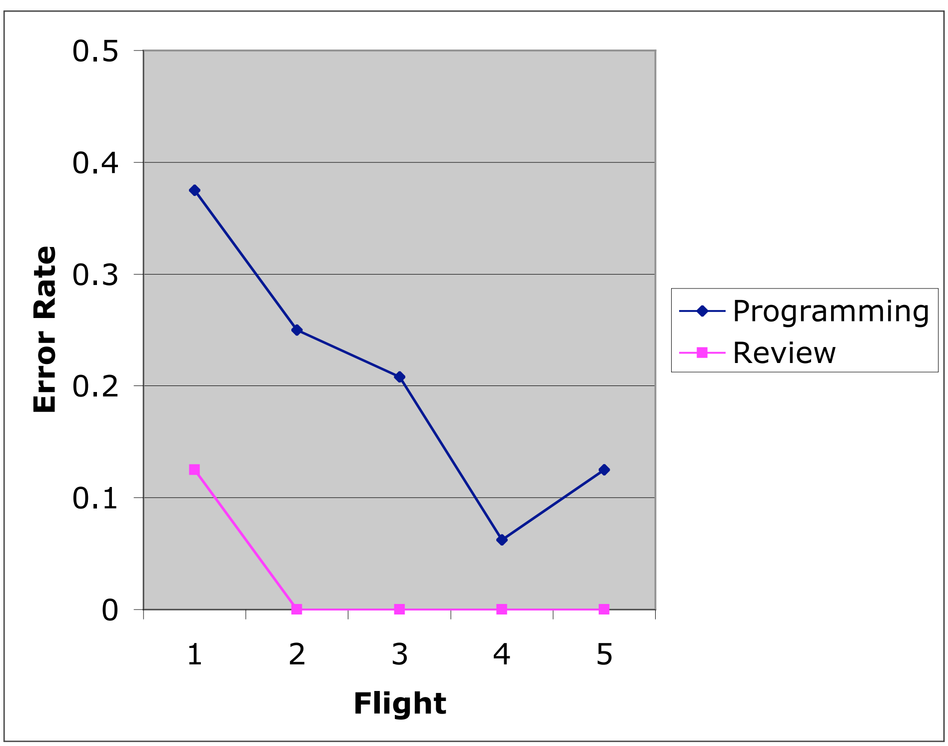

Figure 3: Sub-skills that comprise the Program Route skill.

unsatisfactory performance for the Route Programming task.

The Review sub-skill requires pilots to remember to review the accuracy of a flight route once it is installed. Pilots seemed to have well grasped the importance of checking their work.

Build and Fly a Descent

The Descent skill consisted of two sub-skills shown in Figure 4.

The Programming sub-skill requires pilots to recall the knobs-and-dials procedure required to build a VNAV descent path. Again, the Programming sub-skill was the primary cause of unsatisfactory performance. Since the Descent skill was only practiced twice in flight, the high unsatisfactory rate observed performance on this skill cannot be regarded with any certainty. In fact, the two data points in Figure 4 exactly match the improvement trajectory observed for the programming sub-skill for the Program Route skill (see Figure 4).

The Aircraft Control sub-skill required pilots to meet the crossing restriction they had programmed. Errors on this sub-skill were related to inattention: failure to start the descent at the top-of-descent point computed by the GPS unit, or failure to maintain the target rate of descent.

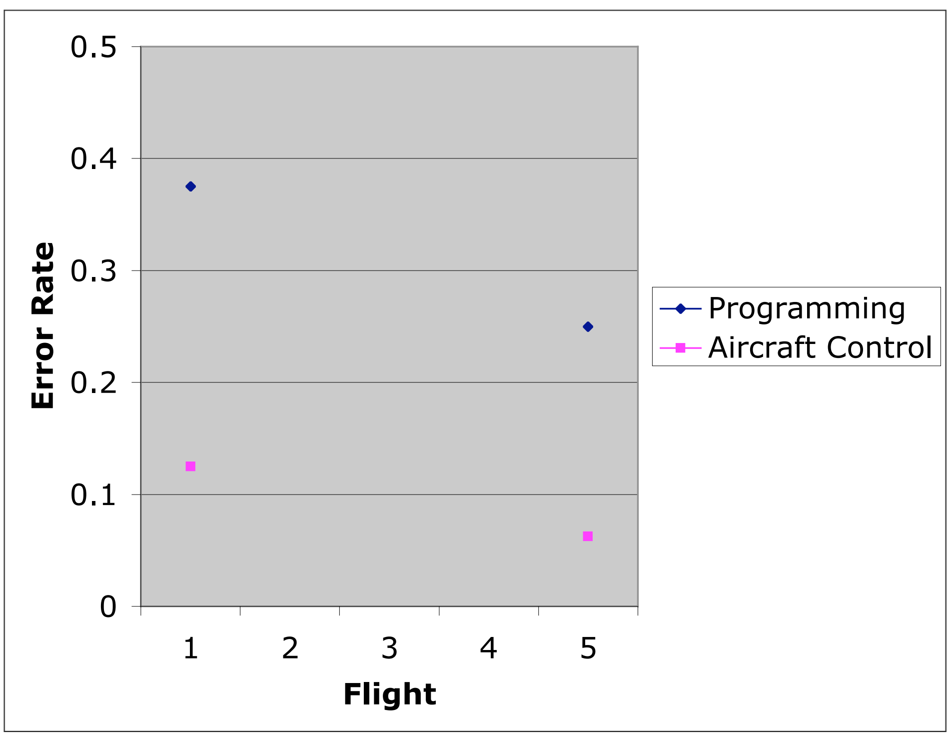

Figure 4: Sub-skills that comprise the Descent skill.

Straight-In GPS Approach

The most basic type of GPS approach was scored with three sub-skills shown in Figure 5.

The Check Approach Active sub-skill is particularly important. Every IFR-approved GPS unit features an annunciation that informs the pilot that all necessary conditions are met to continue an approach beyond the final approach fix and descend to the minimum descent altitude (MDA). Continuing the approach without an approach active indication could result in disastrous consequences since the integrity of the course guidance is not guaranteed. Pilots initially struggled with this important skill but seem to have resolved the problem by the end of the practice flights.

The Aircraft Control sub-skill was a simple measure of how frequently pilots deviated more than 100 feet from a required altitude, or allowed a full-scale deflection of the CDI needle. It is widely known by instructors and pilots alike that aircraft control performance varies when workload is increased and distractions are introduced.

The Position Awareness sub-skill was a reason for unsatisfactory performance when pilots failed to announce their position at an important approach waypoint, or took a required action at an inappropriate place. Several pilots began a descent to the MDA prior to reaching the final approach fix.

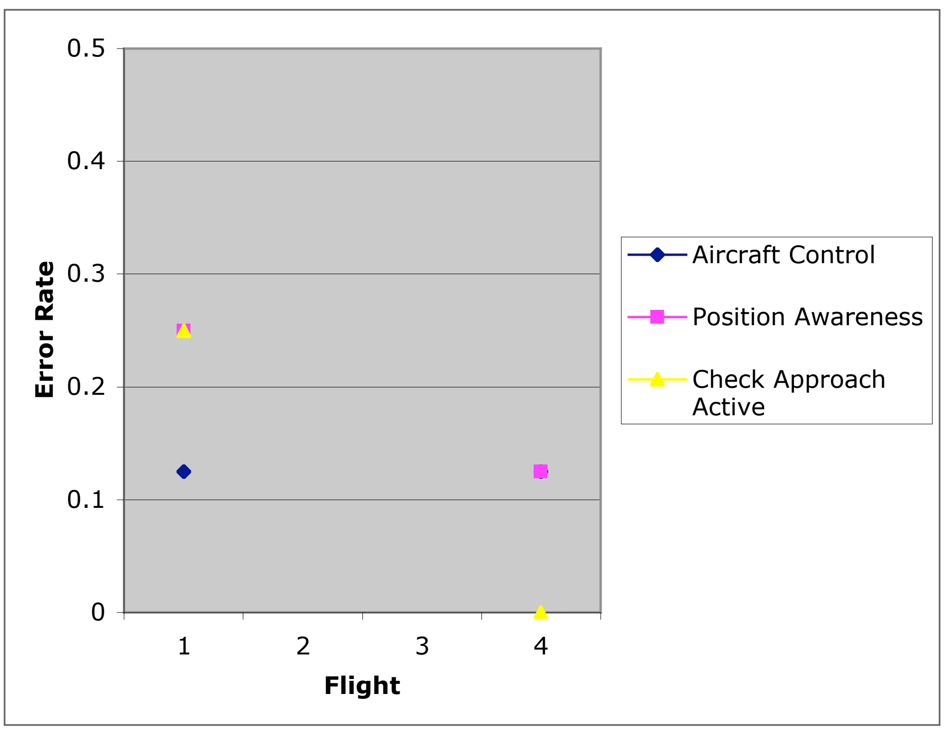

Figure 5: Sub-skills that comprise the Straight-In Approach skill.

Vectored GPS Approach

Five sub-skills shown in Figure 6 comprised this more sophisticated type of GPS approach.

The Set Active Waypoint and Course sub-skill required pilots to change the active waypoint in the GPS computer to a different waypoint that was farther ahead in the approach procedure. This is required when ATC vectors the pilot inside of the initial approach fix in order to shorten an approach. Error rates for this sub-skill never significantly improved over the course of five flights. The consequences of making an error on this sub-skill are severe. Entering the wrong waypoint or course means that the pilot is following a course other than the published approach course.

The Engage OBS Mode sub-skill requires pilots to engage the GPS unit's non-sequencing mode, which allows the pilot to use the OBS knob to dial arbitrary courses to any waypoint. For this type of approach, the pilot dials in the final approach course. Pilots seem to have mastered this sub-skill quickly.

The Re-Engage Sequence Mode sub-skill is somewhat challenging in that it requires pilots to remember to take a future action, a cockpit memory task known to be difficult [Nowinski et al, 2003]. Pilots were still forgetting roughly seven percent of the time even after five practice flights.

Failures on the Position Awareness, Check Approach Active, and Aircraft Control sub-skills continued to be somewhat problematic for vectored approaches.

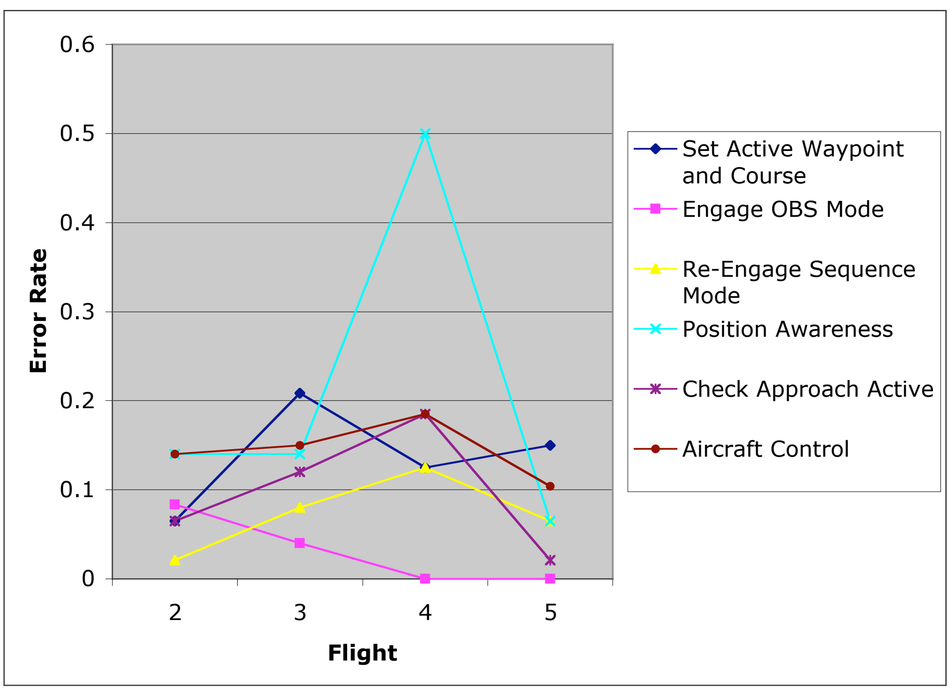

Figure 6: Sub-skills that comprise the Vectored Approach skill.

Missed Approach and Hold

The Missed Approach and Hold skill was scored using the five sub-skills shown in Figure 7.

Identify Missed Approach Point is another sub-skill with potentially serious consequences. Pilots failed to recognize the missed approach point roughly 12% of the time on their second missed approach procedure. One pilot overran the missed approach point by 2.4 NM. This sub-skill is particularly worrisome because the sixteen pilots have already demonstrated their ability to recognize missed approach points using other navigation systems.

Performance on most other sub-skills was similarly unacceptable after two practice trials. Pilots consistently had trouble dialing the correct inbound hold course and in controlling the aircraft.

GPS Approach with Procedure Turn

The GPS Approach with Procedure Turn sub-skill was scored using the five sub-skills shown in Figure 8.

After two practice trials, pilots were still sometimes failing to dial the correct inbound hold course, and were chronically bad at aircraft control.

4. Did similar skills result in similar performance?

Looking at the sub-skills listed in Figures 3 through 8, we notice that some skills require the pilot to perform similar sub-skills. For example, Position Awareness and Aircraft Control are both required sub-skills for all four approach-related skills. Similarly, Engage OBS Mode, Re-Engage Sequence Mode, and Check Approach Active are common to the Vectored and Procedure Turn Approach skills. It is interesting to note whether or not performance on sub-skills were similar across different skills that used them. We might hypothesize that sub-skills that are learned and practiced on one skill might help expedite learning and improve performance on later skills that use them.

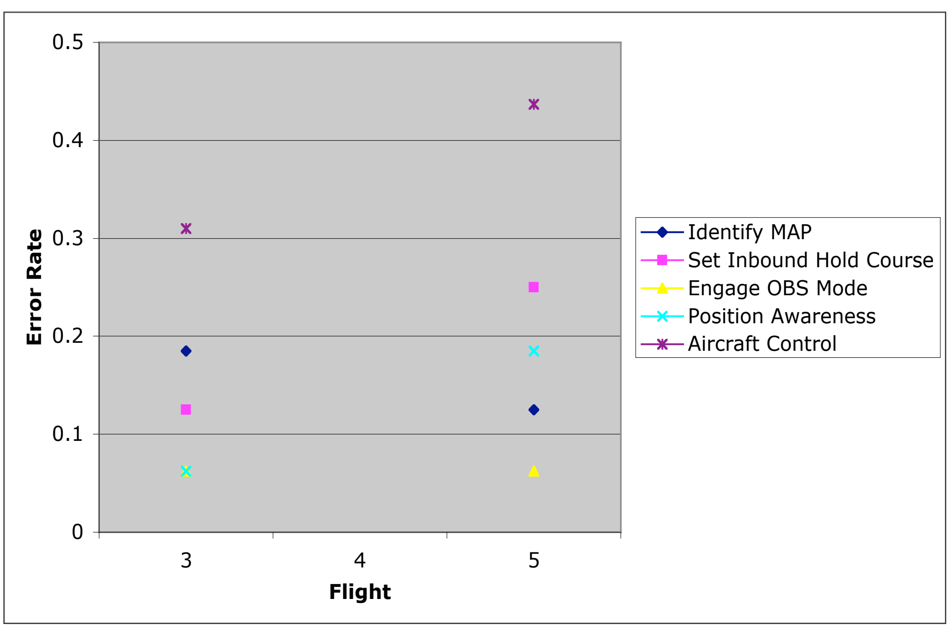

Figure 7: Sub-skills that comprise the Missed Approach and Hold skill.

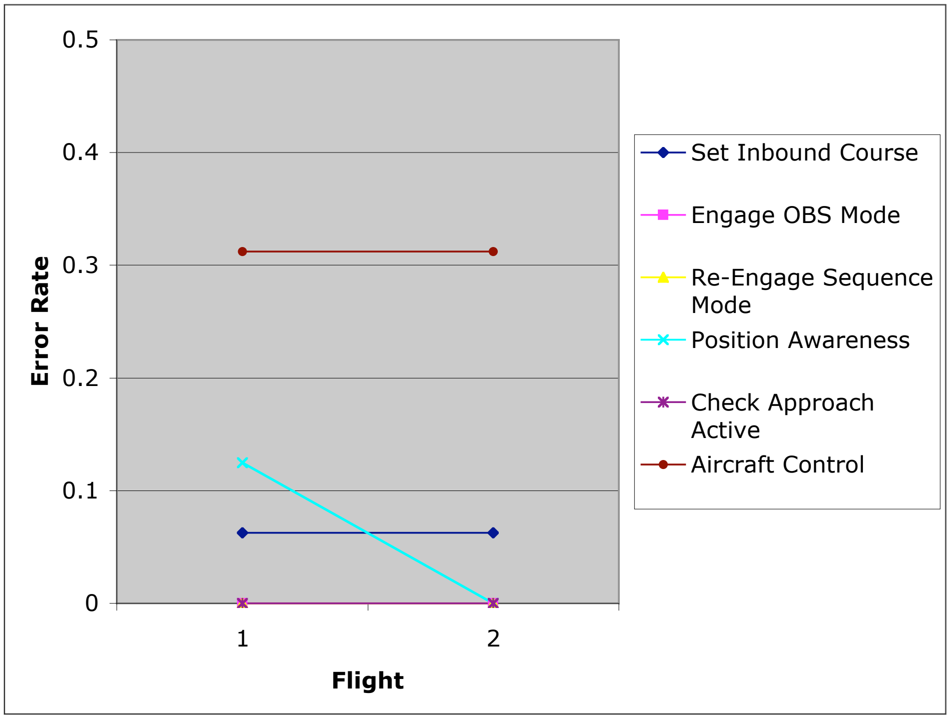

Figure 8: Sub-skills that comprise the Procedure Turn Approach skill.

Development of sub-skills related to engaging or monitoring modes appeared to follow a similar trajectory across skills. The Check Approach Active sub-skill seems to have been soundly learned by Flight 5 for all three GPS approach skills (Straight-in, Vectored, and Procedure Turn). It is not clear whether or not practicing this sub-skill in three different contexts helped to develop a more general skill. The Re-Engage Sequence Mode sub-skill is another memory-related skill that presented most pilots with initial difficulty. This sub-skill was also well mastered across the Vectored and Procedure Turn Approach skills.

There appears to be little similarity among performance on the Aircraft Control sub-skill across the different skills. Pilots who flew within tolerances for some skills were sometimes quite out of control during performance of other skills. This casts doubt on theories that claim that aircraft control is an indicator of a more general division of attention skill that, once mastered, applies to pilot performance in the large.

Conclusion

Even after ground study and five practice flights in an airplane, the data clearly show that the pilots we studied had not yet reached the point of proficiency for most of the IFR GPS skills, even when those skills resemble other skills that pilots had already mastered using other navigation systems. These results strongly suggest that IFR GPS is not a “walk-up-and-use” system for pilots at any experience level. Considerable learning and practice are required to achieve proficiency with flying IFR with GPS.

How much practice is needed then? It is clear that another study must be done in which pilots are permitted to continue practicing until reaching a point of asymptotic performance. It must be noted for the present study that not all skills were practiced on every flight. Indeed, at the end of the training, pilots performed most poorly on skills that they had practiced only a few times. Future studies might be designed to carefully control the number of practice trials for each skill, not just the number of flights. It is important to note that total flight *time* tends to be a poor metric for student practice because different airports afford different degrees of access to suitable instrument practice approaches.

Any future study that allows pilots to train to proficiency faces the challenge of defining what is meant by proficiency. The idea of repeated testing and gathering statistical data on pilot performance casts an interesting light on the problem of defining proficiency. On the typical FAA practical test, applicants are asked to perform each required task just once. If the task is performed satisfactorily, the test proceeds to other areas of operation and tasks. If a pilot is tested on the same skill ten times and performs it satisfactorily nine times, the odds of that pilot passing a check ride on any given day is 90%: fairly good odds. The question still remains: Is that pilot proficient? The answer of course lies in the kind of skill in question. Consider the sub-skill of identifying the missed approach point (MAP). Pilots demonstrated the skill correctly 87.5% of the time on the last practice flight in our study. This is unacceptable because of the serious nature of the task and the consequences of getting it wrong.

Here is where we must recognize an important role played by flight instructors. Unlike pilot examiners who meet with applicants once (or more, in the case of disapproval), flight instructors have access to a more cumulative picture of each student's progress. Flight instructors have the responsibility to recognize intermittent problems and continue training until the problems are resolved. In the case of learning IFR GPS through dual instruction, flight instructors must remind themselves to exercise those same responsibilities that apply to preparation for an FAA certificate or rating. In the case that IFR GPS is learned through self study, pilots must act as their own flight instructors and make careful judgments about their own progress. Clear guidance is surely needed if pilots are to decide for themselves whether they are proficient or require more practice and experience.

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Appendix 1

Script of Events Used for the IFR GPS Practice Flights

Flight 1: SQL-O27-SQL

- SQL-O27
  - Program SQL-Sunol-Tracy-ECA-O27 on ground
  - Announce Sunol
  - Program VNAV ECA @ 3,000
  - Announce Tracy
  - Announce ECA
  - Announce Moter
  - Announce approach active mode
  - Announce Eltro
  - Aircraft control
- O27-SQL
  - Program O27 to SQL on ground
  - Insert Tracy and Sunol
  - Program diversion
  - Look up rwy length and frequency
  - Program Sunol to SQL
  - Aircraft control

Flight 2: SQL-MOD-SCK-LVK-SQL

- SQL-MOD
  - Program SQL-Sunol-Tracy-Cazli-MOD on ground
  - Set OBS 009 to Sunol
  - Set GPS to sequencing mode
  - Announce Sunol
  - Announce Tracy
  - Set OBS 018 to Awoni
  - Announce Awoni
  - Set GPS to sequencing mode
  - Announce approach active mode
  - Announce Wowar
  - Aircraft control
- MOD-SCK
  - Program MOD-SCK on ground
  - Set OBS 291 to Oxjef
  - Set GPS to sequencing mode once established
  - Announce Oxjef
  - Announce approach active mode
  - Announce Ipdew
  - Aircraft control
- SCK-LVK

Program SCK-LVK on ground
Set OBS 246 to Uhhut
Set GPS to sequencing mode
Announce Uhhut
Announce approach active mode
Announce Oyahi
Aircraft control

Flight 3: SQL-STS-KDVO-O69-SQL

SQL-STS
- Program SQL-STS
- Set OBS 321 to Zijbe
- Set GPS to sequencing mode
- Announce Zijbe
- Announce approach active mode
- Announce Gokuw
- Aircraft control

STS-DVO
- Program STS-DVO on ground
- Set OBS course to Oriby
- Announce Oriby
- Announce approach active mode
- Announce Eyeji
- Program direct to SGD
- Set OBS 180 to SGD for hold
- Program SGD-O69
- Aircraft control

DVO-O69
- Set OBS 268 to Ipary
- Set GPS to sequencing mode when established
- Announce approach active mode
- Announce Ipary
- Aircraft control

Flight 4: SQL-MRY-WVI-HAF-SQL

SQL-MRY
- Program SQL-OSI-Sapid-Santy-Mover-SNS-Llynn-MRY on ground
- Engage Heading Select
- Engage VS and arm Altitude Hold
- Set OBS 141 to Sapid
- Arm Nav to capture course
- Set GPS to sequencing mode
- Announce Sapid
- Engage VS and arm Altitude Hold
- Announce Santy
- Engage Heading Select
- Set OBS 286 to Raine

Arm Approach to capture course
Set GPS to sequencing mode when established
Announce approach active mode
Announce Raine
Announce 7.2NM waypoint

MRY-WVI

Program MRY-WVI on ground
Engage VS and arm Altitude Hold
Set OBS 314 to Dyner
Arm Approach to capture course
Set GPS to sequencing mode when established
Announce approach active mode
Announce Dyner

WVI-HAF

Program WVI-HAF on ground
Announce Giruc
Set GPS to OBS mode for hold
Set GPS to sequencing mode
Engage Approach to capture course
Announce approach active mode
Announce Wohli

Flight 5: SQL-O27-SCK-1O3-LVK-SQL

SQL-O27

Program SQL-Sunol-Tracy-ECA-O27 on ground
Announce Sunol
Engage VS and arm Altitude Hold
Program VNAV ECA @ 3,000
Engage VS and arm Altitude Hold
Announce Tracy
Set OBS 090 to Moter
Engage Heading Select and arm Approach
Set GPS to sequencing mode
Announce Moter
Announce approach active mode
Announce Eltro
Program direct Wraps
Use autopilot to accomplish missed approach
Set OBS 180 Wraps for hold
Announce Wraps

Wraps-SCK

Program Wraps-SCK
Set OBS 234 to Oxjef
Engage VS and arm Altitude Hold
Engage Heading Select and arm Approach
Set GPS to sequencing mode when established
Announce approach active mode
Announce Ipdew

SCK-1O3

- Program SCK-1O3
- Set OBS 285 to Quads for PT
- Use autopilot to accomplish PT
- Announce Quads
- Set GPS to sequencing mode inbound to Quads
- Engage approach function
- Announce approach active mode
- Announce Quads

1O3-LVK

- Program 1O3-LVK
- Engage VS and arm Altitude Hold
- Set OBS 246 to Uhhut
- Engage Heading Select and arm Approach
- Set GPS to sequencing mode when established
- Announce Uhhut
- Announce approach active mode
- Announce Oyahi

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12A. DISTRIBUTION/AVAILABILITY STATEMENT

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12B. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Sixteen instrument-rated pilots with no prior experience with IFR GPS completed a program of ground study and five practice flights in an airplane. Eight pilots completed the ground study following a self-study program, while eight pilots received dual ground instruction. The ground study and flight practice covered knowledge and skills required by the instrument rating practical test standard that are affected by the use of IFR GPS. A detailed record was kept of errors made by pilots during each practice flight for six selected skills. The data were analyzed to determine: (1) whether or not the ground study and five practice flights were enough to allow pilots to master the skills; (2) how effective was self study compared to dual instruction; and (3) which skills presented pilots with the most difficulty and accounted for the most errors. The results show that pilots had still not reached proficiency after five practice flights, regardless of ground study method used. Furthermore, pilots were highly similar in the errors they committed while acquiring these new skills. These results show that the learning challenges for proficient IFR GPS are significant.

14. SUBJECT TERMS

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